Influence of mirrored computed tomograms on decision-making for revising surgically treated orbital floor fractures

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Abstract: PURPOSE This study evaluated whether intraoperative imaging with computer-assisted virtual reconstruction would be advantageous in reconstructions of orbital floor fractures. The surgeon's intention to revise a reconstructed primary orbital floor fracture by evaluating a postoperative mirrored computed tomographic (CT) scan was analyzed intraoperatively before wound closure, during inpatient hospitalization, and after hospitalization. The inter-rater agreement and the match of intention to revise and actual revision were analyzed. MATERIALS AND METHODS Fifty-one anonymized postoperative CT scans of patients with a unilateral orbital floor fracture were mirrored using software. These computer-assisted virtual reconstructions were consecutively examined by 4 examiners. Seven of these patients underwent a revision. In the first part, the inter-rater agreements for all 3 times were analyzed. In the second part, the examiners' intentions to revise were compared with the actual performed revisions. RESULTS The overall inter-rater agreements were 0.69 for the intraoperative phase, 0.55 for the in-hospital phase, and 0.39 for the post-hospital phase. The intraoperative inter-rater agreement for each examiner was 0.58 to 0.80. The Fleiss value for the in-hospital and post-hospital phases was lower. The comparison of the examiners' intention to revise and the actual revisions showed that 15 to 24 additional would have been revised. In contrast, 6 of 7 actual revisions would have been revised intraoperatively. The missed actual revision was the same case by all 4 examiners. The accordance of intention to revise with the actual revisions decreased during hospitalization and even more after hospitalization. This study showed strong agreement among examiners for revising anatomically incorrectly reduced orbital floor fractures intraoperatively by evaluating postoperative mirrored CT scans. During the in-hospital and post-hospital phases, the restraints against revision seemed to increase, thus leading to poorer inter-rater agreement. This analysis of postoperative CT scans with computer-assisted virtual reconstructions of the orbit would have led to considerably more revisions intraoperatively, but all actual revisions were detected except for 1 case. This case was the same for all 4 examiners. Operation time would have been prolonged in the additional revised cases, but a better anatomic reconstruction would have been achieved. Furthermore, the intraoperative result of the reconstruction would have been controlled instantly and corrected immediately, if needed. CONCLUSION This study showed that of 6 of 7 actual revisions, implant placement would have been revised intraoperatively by all 4 examiners, if intraoperative imaging with computer-assisted virtual reconstruction of the orbit would have been applied. Therefore, the authors suggest that intraoperative imaging with computer-assisted virtual reconstruction could be advantageous in the prevention of later revisions of orbital floor fractures. In this study, the threshold to revise implant placement intraoperatively seemed to be lower when using intraoperative imaging with virtual reconstructions, because considerably more cases would have been revised intraoperatively by the examiners. In the in-hospital and post-hospital phases, this threshold increased, suggesting the more important role of clinical findings. It is uncertain whether the actual surgeons would have revised the same cases as the examiners if they had used intraoperative imaging with virtual reconstructions for their deliberation. However, the intraoperative inter-rater agreement was good and cost-intensive postoperative revisions might be prevented.

DOI: https://doi.org/10.1016/j.joms.2015.06.159

Originally published at:
Blumer, Michael; Gander, Thomas; Kruse Gujer, Astrid; Seifert, Burkhardt; Rücker, Martin; Lübbers, Heinz-Theo (2015). Influence of mirrored computed tomograms on decision-making for revising surgically treated orbital floor fractures. Journal of Oral and Maxillofacial Surgery, 73(10):1982.e1-1982.e9.
DOI: https://doi.org/10.1016/j.joms.2015.06.159

Influence of mirrored CT scans on decision-making for revising surgically treated orbital floor fractures

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Keywords:
orbital wall fracture, intraoperative computed tomography, computer assisted surgery, surgical navigation

Number of Figures: 1
Number of Tables: 8

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Abstract

Aim of the study

This study evaluates if intraoperative imaging with computer-assisted virtual reconstruction is advantageous in reconstructions of orbital floor fractures. The surgeon's intention to revise a reconstructed primary orbital floor fracture by evaluating a postoperative mirrored CT scan was analyzed at three different times: intraoperatively before wound closure, during inpatient hospitalization, and during the posthospital phase. The interrater-agreement and the match of intention to revise and actual revision were analyzed.

Materials and Methods

Fifty-one anonymized postoperative CT scans of patients with a unilateral orbital floor fracture were mirrored in a software. These computer-assisted virtual reconstructions were consecutively examined by 4 examiners. Seven of these patients underwent a revision. In a first part, the interrater-agreements for all three times were analyzed. In the second part, the examiner's intentions to revise were compared to the actual performed revisions.

Results

The overall interrater-agreement for the intraoperative phase was 0.69, for the in-hospital 0.55, and for the posthospital phase 0.39. The intraoperative interrater-agreement for each examiner was between 0.58 and 0.80. The Fleiss' Kappa for the in-hospital and the posthospital phases was lower.

The comparison of the examiner's intention to revise and the actual revisions showed that 15 to 24 cases more would have been revised. On the other hand, 6 of 7 actual revisions would have been revised intraoperatively. The missed actual revision was the same case by all 4 examiners. The accordance of the intention to revise with the actual revisions is decreasing in the in-hospital and even more in the posthospital phase.

Discussion

This study shows a high agreement between examiners for revising anatomically incorrectly reduced orbital floor fractures intraoperatively by evaluating postoperative mirrored CT scans. In the in-hospital and posthospital phase the restraints for revising seem to rise, thus leading to a poorer interrater-agreement.

This analysis of postoperative CT scans with computer-assisted virtual reconstructions of the orbit would have led to significantly more revisions intraoperatively, but all actual revisions were detected except for 1 case. This case was the same for all 4 examiners. Operation time would have been prolonged in the additionally revised cases, but a better anatomical

reconstruction would have been achieved. Furthermore, the intraoperative result of the reconstruction would have been controlled instantly and corrected immediately if needed.

Conclusion

This study showed that in 6 out of 7 actual revisions the implant placement would have been revised intraoperatively by all 4 examiners, if intraoperative imaging with computer-assisted virtual reconstruction of the orbit would have been applied. Therefore the authors suggest that intraoperative imaging with computer-assisted virtual reconstruction could be advantageous in prevention of later revisions of orbital floor fractures. In this study the threshold to revise implant placement intraoperatively seems to be lower when using intraoperative imaging with virtual reconstructions, given that significantly more cases would be revised intraoperatively by the examiners. In the inhospital and the posthospital phases this threshold rises suggesting the more important role of the clinical findings. It stays uncertain if the actual surgeons would have revised the same cases as the examiners having intraoperative imaging with virtual reconstructions for their decision. But the intraoperative interrater-agreement is good and cost-intensive postoperative revisions may be prevented.

Introduction

Orbital floor fractures are common in midfacial fractures [1] deriving from facial trauma. Various studies have discussed indications and timing for operative repair of orbital floor fractures because oculo-facial surgery is not risk-free[2]. If not operated on in time and appropriately, complications like enophthalmia or diplopia may occur[3-6].

New surgical and imaging techniques have improved both the functional and aesthetic outcomes of reconstructions[6-8], and surgical navigation has become an established technique in oral and maxillofacial surgery[9-12]. Intraoperative MDCT (multidetector computed tomography) and CBCT (cone beam computed tomography) scans to confirm ideal reconstruction are described in the literature as effective[13-24].

However, to our knowledge, no study has investigated the influence of computer-assisted virtual reconstructions of the orbit on the surgeon's decision to revise a reconstruction of an orbital floor fracture.

The aim of this study is to test whether a surgeon would revise the result of a primary orbital floor reconstruction by reviewing a mirrored postoperative CT scan at 3 particular times: 1) intraoperatively before wound closure, 2) during inpatient hospitalization, or 3) in the posthospital phase. The extent to which these revisions correspond to effectively revised cases is based on clinical results. This is a means to evaluate whether intraoperative imaging is advantageous.

Material and Methods

Anonymized postoperative CT scans of 51 patients with a unilateral orbital floor fracture operation were included in this study. All of them were operated on, and postoperative imaging was conducted between September 2009 and December 2012 in the clinic of cranio-maxillofacial surgery at the Universitätsspital Zurich. None of the patients had underwent intraoperative imaging during the surgical procedure. Seven of the 51 patients subsequently underwent revision surgery after the surgical repair.

These postoperative CT scans then were imported into the Brainlab iPlan Net software (Brainlab AG, Kapellenstrasse 12, 85622 Feldkirchen, Germany) as described in a previous study[14]. The autosegmentation function of the program was used on the unaffected orbit to obtain a virtual 3-D template. The computed 3-D template then was controlled and manually trimmed using the given software tools if necessary (Fig. 1).

This 3-D template was mirrored and manually superimposed to the best fit onto the affected orbit using landmarks as the orbital roof in the sagittal plane and the orbital rim in the coronal plane (Fig. 1). Finally, these modified postoperative CT scans were saved on the clinic server as DICOM data sets to be analyzed by the examiners. Information about the affected side, injury pattern and the materials used for reconstruction (PDS, titanium meshes or both) was assessed using these anonymized postoperative CT scans.

Subsequently, whether a surgeon would revise the surgically repaired orbital floor fracture was analyzed using the data sets. Examiners assessed the postoperative CT scans with the mirrored, unaffected orbit as a reference. Deliberate clinical symptoms were not included. Two experienced consultants (examiner 1 and 3) and two residents (examiner 2 and 4) analyzed the data sets and decided if a revision was favorable. The decision-making was separated for three different time periods: 1) when the surgeon would see the CT scan intraoperatively before closing the surgical access, 2) during the inpatient hospitalization, and 3) in the posthospital phase.

These results were analyzed for interrater-agreement, and the examiner's intentions to revise were compared with the actual revisions. Each measurement was analyzed for the whole study population, for cases treated with PDS and for cases with titanium meshes.

Statistical analyses for the patient collective were performed using Excel (Microsoft Corporation, Redmond, USA). The interrater-agreement was assessed using Fleiss' Kappa[25]. For these calculations, the Stata 13.1 program (StataCorp LP, College Station, TX, USA) was used, and to calculate the 95 % confidence interval (CI) 5000 bootstrap replications were applied. The agreement between the examiners is usually graded according to Landis and Koch[26]: poor < 0.00, slight 0.01–0.20, fair 0.21–0.40, moderate 0.41–0.60, substantial 0.61–0.80, and almost perfect 0.81–1.00.

The analyses of the comparison between the examiner's decisions and actual revisions were performed using the McNemar test and the IBM SPSS Statistics program (Version 22, IBM Corporation, Armonk, NY, USA).

A p-value < 0.05 was considered to be statistically significant.

All CT scans were medically indicated. All patients had signed forms indicating their consent to the use of their data for study purposes. The study design met the criteria in paragraphs 4a and 4b of the guidelines of the cantonal (state) ethics committee (version dated May 21, 2010) and therefore was exempt from individual approval. Hence, the study design meets the guidelines of the Declaration of Helsinki Concerning Ethical Principles for Medical Research Involving Human Subjects.

Results

<u>Patient collective</u>

Of the 51 analyzed postoperative CT scans, 34 patients were male (67 %) and 17 were female (33 %). The mean age was 45.6 years (range 14 to 81). In 27 (53 %) cases the left side was affected, and in 24 (47 %), the right side was affected.

There were 30 isolated orbital floor fractures found (59 %); 21 patients showed additional injuries (41 %). The materials used for reconstruction were PDS sheets in 19 cases (37 %), titanium meshes in 20 (39 %), and titanium meshes combined with PDS sheets in 12 (24 %). These results are shown in Table 1.

<u>Interrater-agreement</u>

Next, the interrater-agreement was analyzed using the Fleiss' Kappa test. A Kappa of 0.69 (CI 95 % 0.55 - 0.82) was found for the overall interrater-agreement for the intraoperative decision for revision. The Kappa for an in-hospital revision was found to be 0.55 (CI 95 % 0.34 - 0.72) and 0.39 (CI 95 % -0.02 - 0.62) for posthospital revision (Table 2). The values for PDS and titanium mesh reconstructions are also shown. No statistical value was computed for the posthospital PDS cases since none of the examiner would have revised in any of these 19 cases.

The interrater-agreement for every examiner was analyzed separately. For the intraoperative decision, examiners 1 and 2 found a Kappa of 0.76. Examiners 1 and 3 found one of 0.80; examiners 1 and 4 found one of 0.58. Comparing examiner 2 with examiner 3, a Kappa of 0.80 was found; it was 0.58 for examiners 2 and 4. Meanwhile, examiners 3 and 4 found a Kappa of 0.62 (Table 3).

Analyzing the interrater-agreement for the in-hospital decisions for revision, examiners 1 and 2 found a Kappa of 0.55; examiners 1 and 3 found one of 0.73; and examiners 1 and 4 found one of 0.37. Examiners 2 and 3 found a Kappa of 0.59, examiners 2 and 4 one of 0.58, and examiners 3 and 4 one of 0.56. The results are shown in Table 4.

The interrater-agreement for the posthospital decisions for revision showed a Kappa of 0.66 for examiners 1 and 2, one of 0.66 for examiners 1 and 3, and one of 0.48 for examiners 2 and 3. The Kappa value for examiner 4 compared to all other examiners was 0.00 (Table 5).

<u>Comparison of examiner's intention to revise with actual revisions</u>

The examiner's intention to revise was compared to the actual revisions using the McNemar test. Intraoperatively, examiner 1 would have revised in 22 cases where no actual revision occurred. One actual revision would not have occurred, and 6 (of the 7 actual revisions) would have been revised intraoperatively (p = <0.001). Examiner 2 would have revised 24 more cases; the number was 23 for examiner 3 and 15 for examiner 4. One actual revision would have been missed, and 6 actual revisions would have been revised (Table 6). The missed actual revision was the same case for all 4 examiners. The results of the separated groups are also shown.

In the in-hospital phase, examiner 1 would have revised 4 more cases; 4 actual revisions would not have taken place; and 3 times, the revisions matched (p = 1.0). Examiner 2 would have revised in 11 cases where no actual revision occurred. In 3 cases, an actual revision would have not been made, and in 4 cases, the decision and actual revisions matched (p =

0.06). Examiner 3 would have revised six more cases, in five cases decision and revision match and in two cases an actual revision would have been not performed (p-value 0.29). Examiner 4 would have revised 15 more cases; in 1 case, an actual revision would have not taken place, and in 6 cases, the decision and revision matched ($p = 0.001$). Attached are the results for separated groups (Table 7).

In the posthospital phase, none of the examiners would have revised any case that was not actually revised. Six actual revisions would have been not revised by examiner 1, 5 each by examiners 2 and 3, and all 7 by examiner 4. The decision to revise and the actual revision matched in 1 case with examiner 1, in 2 cases with examiners 2 and 3, and in none of the cases with examiner 4. The p-values are shown in Table 8 with the additional results for separation of the reconstruction groups.

Discussion

This study found a moderate overall interrater-agreement for the intraoperative decision finding by evaluating postoperative mirrored CT scans according to Landis and Koch. When analyzing each examiner pair for intraoperative decisions to revise separately, the interrater-agreement was moderate to substantial. In the in-hospital and posthospital phases, it decreased.

For the authors of the present study, these results show the high importance of postoperative functional and aesthetic symptoms in order to revise anatomically the imperfectly reduced orbital fractures in a later course. Even though there exist studies with good postoperative results after delayed reconstruction at up to 10 weeks[27, 28], other studies found less postoperative diplopia and enophthalmos when early reconstruction (in the first 2 weeks) took place[29, 30].

The restraints of revising anatomically imperfectly reduced reconstructions seem to rise when primary reconstruction takes place, which is shown by less agreement between the examiners in the in-hospital and posthospital phase. Examiner 4 would not have attempted a revision of a once-reduced orbital fracture in the posthospital phase after evaluating postoperative CT scans with a virtual reconstructed orbit, leading to poor interrater-agreement.

Meanwhile, this study shows a high agreement for revising anatomically incorrectly reduced orbital floor fractures intraoperatively. For the authors of the present study, these results show that intraoperative imaging with computer-assisted virtual reconstruction of the orbit would be favorable. Anatomically incorrectly reduced orbital floor fractures would be detected immediately and reliably. The agreement between surgeons seems to be consistent and good.

In this study 7 patients underwent a revision of the primary orbital floor reconstruction. These actual revisions were compared to the examiners' intention to revise at the 3 abovementioned times.
Intraoperative CT scans with computer-assisted virtual reconstruction would lead to significantly more revisions. The 4 examiners would have revised the intraoperative results in 15 to 24 more cases. This finding is consistent with higher intraoperative revision-rates in previous studies that analyzed intraoperative imaging solely (without virtual reconstructions) [19, 21, 22]. The threshold for revising seems to be significantly lower intraoperatively than postoperatively. But all actual later revisions were detected, except for 1 case, by all examiners.
These findings show that 6 out of 7 later revisions would probably have been prevented using intraoperative imaging with virtual reconstruction of the orbit. For the authors of this study, this is a strong reason for using intraoperative imaging with computer-assisted virtual reconstruction. At last it stays uncertain whether or not the actual surgeon would have decided as the examiners in the specific operation. Then again the good intraoperative interrater-agreement makes it seem likely.
The missed actual revision was the same for all 4 examiners. This leads to the assumption that a clinical finding must have led to the revision, which may be undetectable by CT scan. This emphasizes good interrater-agreement in the intraoperative phase.
On the other hand, many more cases would have been revised that were not in actuality. But the examiners would have corrected the implant placement intraoperatively for a better anatomical reconstruction. Even though the operation time would have been prolonged, no second operation would have been necessary, and the authors assume that a better anatomical reconstruction would have been achieved. Keeping in mind that literature[8, 31-33] describes enophthalmos, diplopia, and disturbances of eye motility as results of incorrect anatomical reconstruction, this extra time for intraoperative imaging and (if needed) immediate intraoperative revision of the orbit seem more than acceptable. Furthermore, the examiners were consistent with the higher number of cases they would have revised. The reconstruction results may be controlled instantly and corrected immediately if needed. A beneficial finding that is also described in previous studies of intraoperative imaging[15, 18, 21, 23].
The limitation of this study is that no clinical data of the postoperative results (e.g., the grade of enophthalmos or diplopia) is included. So it is uncertain whether all patients with no actual revision had a good aesthetic and functional result.
In the in-hospital and posthospital phases, the match of actual revised orbits and the intention to revise decreased. The actual revisions matched from 0 to 6 cases with the intention of the examiners. This finding shows that the intention to revise in a later onset is

more dependent on the clinical status than of mirrored CT scans; in the posthospital phase, none of the examiners would have revised any orbit that was not actually revised. Secondary orbit reconstruction is challenging. An enophthalmos may be treated successfully, but diplopia may remain after the revision[32]. So the indication for a revision has to be set carefully and planned thoroughly. If the possibility of a correct anatomical reduction is feasible (e.g., by using intraoperative imaging with computer-assisted virtual reconstruction), it should be sought. This is congruent with conclusions of a recent study that analyzed results of intraoperative CT scans[19]. Furthermore the authors of the study conclude that immediate feedback may shorten the learning curve for proficiency in maxillofacial reconstruction; as the opportunity of immediate feedback is given.

The use and benefits of intraoperative imaging are described in literature. Mostly CBCT is used, which has a poorer contrast than Medical CT scans. High-contrast structures as bone and radio-opaque reconstruction materials may be imaged comparable to Medical CT scans and therefore adequately assessed[23]. In the same study the 3D C-arm system is described as an effective tool for intraoperative evaluation of reduction in ZMC fractures. The intraoperative imaging was used for reduction through just a single intraoral approach with subsequent radiological reduction control and evaluation of the need for an additional orbital reconstruction. Just 3 out of 21 patients with ZMC fractures needed orbital reconstruction after fracture reduction (2 orbital floor, 1 lateral floor). The authors concluded, that intraoperative imaging helps to reduce operation time and morbidity due to fewer surgical approaches needed. Furthermore, if intraoperative imaging is carried out there appears to be no more need for postoperative imaging. In the long term they assessed 4 minor facial asymmetries of the zygomatic prominences by using a photometric method. But no preoperative photographs were available to objectify these findings and no enophthalmos were found.

In this study PDS was used for reconstruction in 37 % of the cases. All of those reconstructions would intraoperatively not be visible utilizing a CBCT. Therefore this material would not benefit from the technique. In addition it might change its exact form during the degradation process especially in bigger defects; another reason it would benefit less from immediate intraoperative imaging. In this study in all cases treated with PDS no actual revision took place, which is likely to the fact that this material was used for the reconstruction of smaller defects of the orbit. The examiners would have revised 7 to 9 cases more intraoperatively and 3 to 7 cases more in the inhospital phase. It can be suggested, that these cases would have been revised utilizing titanium meshes instead of PDS. As mentioned in the material and method section, the position of the reconstruction was identifiable in all cases and was analyzed using the computer-assisted virtual reconstruction of the orbit. As the rater’s decision was solely based on the achieved position of the reconstructed orbital wall there is no actual influence of the reconstruction material on the study results. Merging intraoperative images with computer-assisted virtual reconstructions (planned in preoperative CT scans) in order to assess the correct reconstruction of the orbit might be feasible also when using PDS as reconstruction material. However, the position of radio-opaque reconstruction materials may be assessed more adequate. This finding is supported by a slightly higher revision rate for the intraoperative titanium cases. But as mentioned above, titanium meshes are commonly utilized in bigger defects where reconstruction is more demanding anyway. Thus leading to a higher revision rate. Furthermore titanium meshes can be reshaped leading to a more predictable result of the revision.

Nevertheless, the results and the success rate in identifying the correct cases to revise obviously only applies to the observers that took part in the study. It strongly suggests that the concept of intraoperative imaging and virtual mirroring might be able to prevent later revisions. It also suggests, that the decision is dependent of the rater and therefor four-eyes-principle might be beneficial.

Conclusion

This study showed that in 6 out of 7 actual revisions the implant placement would have been revised intraoperatively by all 4 examiners, if intraoperative imaging with computer-assisted virtual reconstruction of the orbit would have been applied. Therefore the authors suggest that intraoperative imaging with computer-assisted virtual reconstruction could be advantageous in prevention of later revisions of orbital floor fractures. In this study the threshold to revise implant placement intraoperatively seems to be lower when using intraoperative imaging with virtual reconstructions, given that significantly more cases would be revised intraoperatively by the examiners. In the inhospital and the posthospital phases this threshold rises suggesting the more important role of the clinical findings. It stays uncertain if the actual surgeons would have revised the same cases as the examiners having intraoperative imaging with virtual reconstructions for their decision. But the intraoperative interrater-agreement is good and cost-intensive postoperative revisions may be prevented.

Tables

sex	
male	34 (67%)
female	17 (33%)
mean age	45.6 (14-81)
affected side	
left	27 (53%)
right	24 (47%)
material	
PDS	19 (37%)
titan	20 (39%)
both	12 (24%)
injury type	
orbital floor	30 (59%)
additional injury	21 (41%)

Table 1: Patient collective of the 51 analyzed anonymized postoperativ CT scans.

Overall interrater-agreement

	Intraoperative	Inhospital	Posthospital
All	0.69 (0.55 - 0.82)	0.55 (0.34 - 0.72)	0.39 (-0.02 - 0.66)
PDS	0.57 (0.33 - 0.81)	0.60 (0.12 - 0.91)	---
Titanium	0.74 (0.55 - 0.90)	0.52 (0.27 - 0.75)	0.38 (-0.02 - 0.66)

Table 2: Kappa values for the overall interrater-agreement.

Intraoperative interrater-agreement			
	examiner 2	examiner 3	examiner 4
examiner 1	0.76 (0.58 - 0.94)	0.80 (0.64 - 0.07)	0.58 (0.36 - 0.80)
examiner 2	---	0.80 (0.63 - 0.97)	0.58 (0.38 - 0.79)
examiner 3	---	---	0.62 (0.41 - 0.82)

Table 3: Interrater-agreement for each examiner for the intraoperative decisions for revision (CI 95%).

Inhospital interrater-agreement			
	examiner 2	examiner 3	examiner 4
examiner 1	0.55 (0.30 - 0.81)	0.73 (0.49 - 0.98)	0.37 (0.15 - 0.59)
examiner 2	---	0.59 (0.34 - 0.84)	0.58 (0.35 - 0.80)
examiner 3	---	---	0.56 (0.35 - 0.78)

Table 4: Interrater-agreement for each examiner for the inhospital decisions for revision (CI 95%).

Posthospital interrater-agreement			
	examiner 2	examiner 3	examiner 4
examiner 1	0.66 (0.03 - 1.00)	0.66 (0.03 - 1.00)	0.00
examiner 2	---	0.48 (-0.14 - 1.00)	0.00
examiner 3	---	---	0.00

Table 5: Interrater-agreement for each examiner for the posthospital decisions for revision (CI 95%).

Intraoperative		examiner 1		examiner 2		examiner 3		examiner 4	
		No revision	Revision	No revision	Revision	No revision	Revision	No revision	Revision
All	No actual revision	22	22	20	24	21	23	29	15
	Actual revision	1	6	1	6	1	6	1	6
	p-value	<0.001		<0.001		<0.001		0.001	
PDS	No actual revision	12	7	10	9	10	9	12	7
	Actual revision	0	0	0	0	0	0	0	0
	p-value	0.02		0.004		0.004		0.02	
Titanium	No actual revision	10	15	10	15	11	14	17	8
	Actual revision	1	6	1	6	1	6	1	6
	p-value	0.001		0.001		0.001		0.04	

Table 6: Comparison of the examiner's intraoperative decisions to revise with the actual revisions (results are also subdivided in cases reconstructed with PDS and titanium mesh).

Inhospital		examiner 1		examiner 2		examiner 3		examiner 4	
		No revision	Revision	No revision	Revision	No revision	Revision	No revision	Revision
All	No actual revision	40	4	33	11	38	6	29	15
	Actual revision	4	3	3	4	2	5	1	6
	p-value	1		0.06		0.29		0.001	
PDS	No actual revision	16	3	14	5	15	4	12	7
	Actual revision	0	0	0	0	0	0	0	0
	p-value	0.25		0.063		0.13		0.07	
Titanium	No actual revision	24	1	19	6	23	2	17	8
	Actual revision	4	3	3	4	2	5	1	6
	p-value	0.38		0.51		1		0.04	

Table 7: Comparison of the examiner's inhospital decisions to revise with the actual revisions (results are also subdivided in cases reconstructed with PDS and titanium mesh).

Posthospital		examiner 1		examiner 2		examiner 3		examiner 4	
		No revision	Revision	No revision	Revision	No revision	Revision	No revision	Revision
All	No actual revision	44	0	44	0	44	0	44	0
	Actual revision	6	1	5	2	5	2	7	0
	p-value	0.03		0.06		0.06		0.02	
PDS	No actual revision	19	0	19	0	19	0	19	0
	Actual revision	0	0	0	0	0	0	0	0
	p-value	---		---		---		---	
Titanium	No actual revision	25	0	25	0	25	0	25	0
	Actual revision	6	1	5	2	5	2	7	0
	p-value	0.03		0.06		0.06		0.2	

Table 8: Comparison of the examiner's posthospital decisions to revise with the actual revisions (results are also subdivided in cases reconstructed with PDS and titanium mesh).

References

1. Salentijn EG, van den Bergh B, Forouzanfar T: A ten-year analysis of midfacial fractures. J Craniomaxillofac Surg 41:630, 2013

2. Burnstine MA: Clinical recommendations for repair of orbital facial fractures. Curr Opin Ophthalmol 14:236, 2003

3. Biesman BS, Hornblass A, Lisman R, Kazlas M: Diplopia after surgical repair of orbital floor fractures. Ophthal Plast Reconstr Surg 12:9, 1996

4. Folkestad L, Westin T: Long-term sequelae after surgery for orbital floor fractures. Otolaryngol Head Neck Surg 120:914, 1999

5. Tan Baser N, Bulutoglu R, Celebi NU, Aslan G: Clinical management and reconstruction of isolated orbital floor fractures: the role of computed tomography during preoperative evaluation. Ulus Travma Acil Cerrahi Derg 17:545, 2011

6. Feichtinger M, Ardjomand N, Santler G, Langmann A, Karcher H: Orbital revision after trauma. Ophthalmology 113:2112.e1, 2006

7. Ewers R, Schicho K, Undt G, Wanschitz F, Truppe M, Seemann R, Wagner A: Basic research and 12 years of clinical experience in computer-assisted navigation technology: a review. Int J Oral Maxillofac Surg 34:1, 2005

8. Schramm A, Suarez-Cunqueiro MM, Rucker M, Kokemueller H, Bormann KH, Metzger MC, Gellrich NC: Computer-assisted therapy in orbital and mid-facial reconstructions. Int J Med Robot 5:111, 2009

9. Gellrich NC, Schramm A, Hammer B, Rojas S, Cufi D, Lagreze W, Schmelzeisen R: Computer-assisted secondary reconstruction of unilateral posttraumatic orbital deformity. Plast Reconstr Surg 110:1417, 2002

10. Lubbers HT, Jacobsen C, Matthews F, Gratz KW, Kruse A, Obwegeser JA: Surgical navigation in craniomaxillofacial surgery: expensive toy or useful tool? A classification of different indications. J Oral Maxillofac Surg 69:300, 2011

11. Schmelzeisen R, Gellrich NC, Schoen R, Gutwald R, Zizelmann C, Schramm A: Navigation-aided reconstruction of medial orbital wall and floor contour in cranio-maxillofacial reconstruction. Injury 35:955, 2004

12. Essig H, Dressel L, Rana M, Rana M, Kokemueller H, Ruecker M, Gellrich NC: Precision of posttraumatic primary orbital reconstruction using individually bent titanium mesh with and without navigation: a retrospective study. Head Face Med 9:18, 2013

13. Lubbers HT, Terzic A, Zemann W, Jacobsen C, Obwegeser J, Kruse A: Computer assisted maxillofacial surgery. Minerva Chir 66:469, 2011

14. Terzic A, Scolozzi P: Image guided surgical navigation integrating "mirroring" computational planning based on intra-operative cone-beam CT imaging: a promising new approach for management of primary bilateral midfacial fractures. Comput Aided Surg 16:170, 2011

15. Heiland M, Schulze D, Blake F, Schmelzle R: Intraoperative imaging of zygomaticomaxillary complex fractures using a 3D C-arm system. Int J Oral Maxillofac Surg 34:369, 2005

16. Hoelzle F, Klein M, Schwerdtner O, Lueth T, Albrecht J, Hosten N, Felix R, Bier J: Intraoperative computed tomography with the mobile CT Tomoscan M during surgical treatment of orbital fractures. Int J Oral Maxillofac Surg 30:26, 2001

17. Imai T, Michizawa M, Fujita G, Shimizu H, Ota Y, Kitamura T, Ichiyanagi H, Kai T: C-arm-guided reduction of zygomatic fractures revisited. J Trauma 71:1371, 2011

18. Pohlenz P, Blake F, Blessmann M, Smeets R, Habermann C, Begemann P, Schmelzle R, Heiland M: Intraoperative cone-beam computed tomography in oral and maxillofacial surgery using a C-arm prototype: first clinical experiences after treatment of zygomaticomaxillary complex fractures. J Oral Maxillofac Surg 67:515, 2009

19. Shaye DA, Tollefson TT, Strong EB: Use of intraoperative computed tomography for maxillofacial reconstructive surgery. JAMA Facial Plast Surg 17:113, 2015

20. Stanley RB, Jr.: Use of intraoperative computed tomography during repair of orbitozygomatic fractures. Arch Facial Plast Surg 1:19, 1999

21. Stuck BA, Hulse R, Barth TJ: Intraoperative cone beam computed tomography in the management of facial fractures. Int J Oral Maxillofac Surg 41:1171, 2012

22. van Hout WM, Van Cann EM, Muradin MS, Frank MH, Koole R: Intraoperative imaging for the repair of zygomaticomaxillary complex fractures: a comprehensive review of the literature. J Craniomaxillofac Surg 42:1918, 2014

23. Wilde F, Lorenz K, Ebner AK, Krauss O, Mascha F, Schramm A: Intraoperative imaging with a 3D C-arm system after zygomatico-orbital complex fracture reduction. J Oral Maxillofac Surg 71:894, 2013

24. Wilde F, Schramm A: Intraoperative imaging in orbital and midface reconstruction. Facial Plast Surg 30:545, 2014

25. Fleiss JL: Measuring nominal scale agreement among many raters. Psychological Bulletin 76:378, 1971

26. Landis JRK, G.G.: The measurement of observer agreement for categorical data. Biometrics 33:159, 1977

27. Dingman RO, Harding RL: Treatment of malunion fractures of facial bones. Plast Reconstr Surg (1946) 7:505, 1951

28. Lee J, Tahiri Y, Roy AA, Lessard L: Delayed repair of lateral orbital wall and orbital floor fracture. J Craniofac Surg 24:34, 2013

29. Becelli R, Renzi G, Perugini M, Iannetti G: Craniofacial traumas: immediate and delayed treatment. J Craniofac Surg 11:265, 2000

30. Hosal BM, Beatty RL: Diplopia and enophthalmos after surgical repair of blowout fracture. Orbit 21:27, 2002

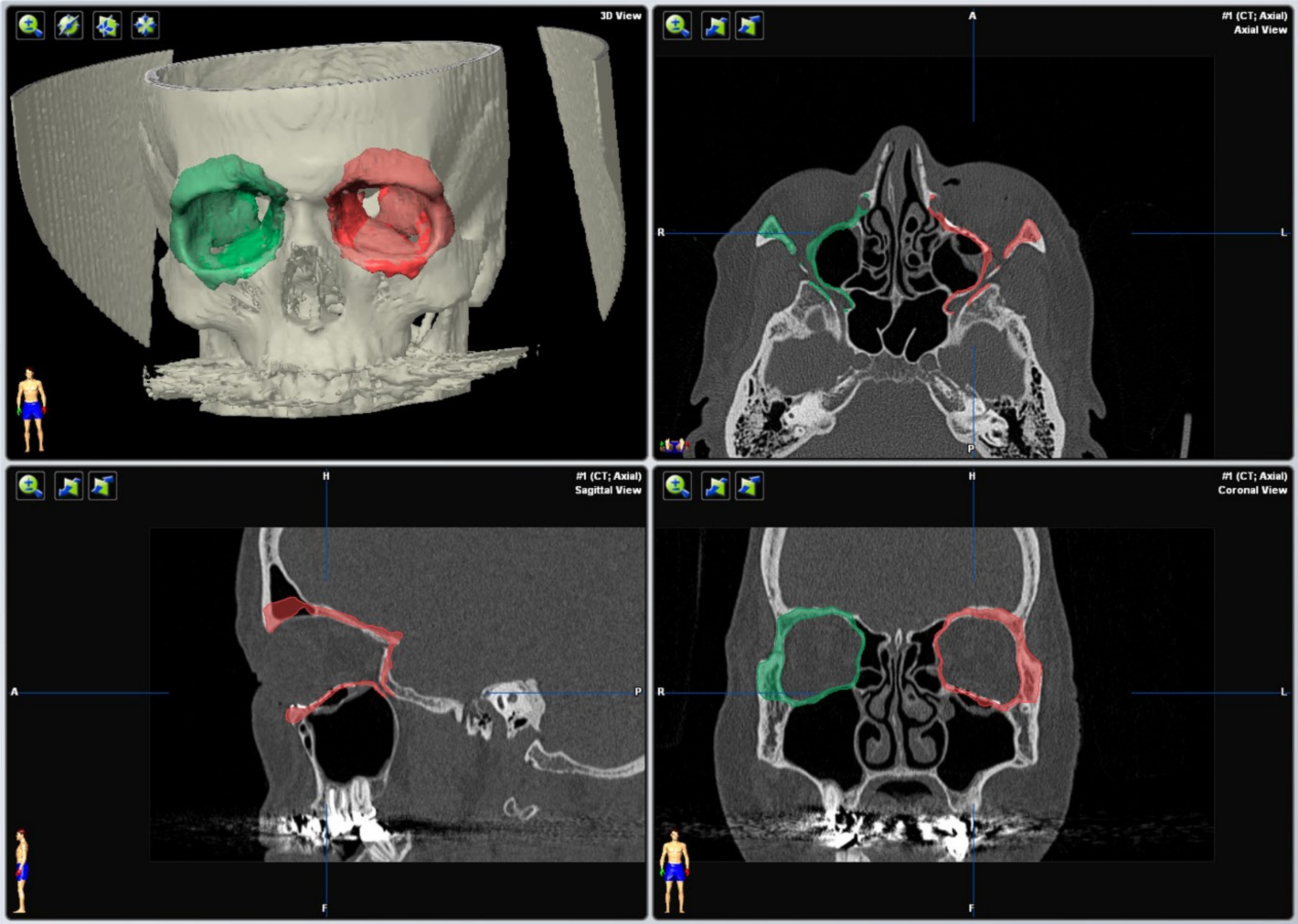
31. Jaquiery C, Aeppli C, Cornelius P, Palmowsky A, Kunz C, Hammer B: Reconstruction of orbital wall defects: critical review of 72 patients. Int J Oral Maxillofac Surg 36:193, 2007

32. Lieger O, Richards R, Liu M, Lloyd T: Computer-assisted design and manufacture of implants in the late reconstruction of extensive orbital fractures. Arch Facial Plast Surg 12:186, 2010

33. Manolidis S, Weeks BH, Kirby M, Scarlett M, Hollier L: Classification and surgical management of orbital fractures: experience with 111 orbital reconstructions. J Craniofac Surg 13:726, 2002

Figure legends

Fig. 1: First the autosegmentation function of the software was used on the unaffected orbit for a computed 3-D template (green). This template was searched for possible errors and manually trimmed if needed. Afterwards the template was mirrored and superimposed resulting in the virtual reconstruction of the affected orbit (red). In this case the virtual reconstruction of the fractured orbit shows the correct shape and position of the implant.


3D View
#1 (CT; Axial)
Axial View
A
R
L
P
#1 (CT; Axial)
Sagittal View
H
A
P
F
#1 (CT; Axial)
Coronal View
H
R
L
F